Geochemical Characterization and Management Challenges of Groundwater in Dhaka City, Bangladesh.

Shahida Akter[1*], Anwar Saadat Mohammad Sayem[1], Md. Rashedul Hasan[1] and Riyadul Islam[1]

[1]Geological Survey of Bangladesh, Bangladesh

(*Corresponding E-mail: shahidagsb@gmail.com)

Abstract: Effective groundwater management is critical for ensuring public health and sustainable water use, particularly in rapidly urbanizing regions such as Dhaka City, Bangladesh. This study assesses groundwater quality and its implications for human health through geochemical analysis of thirty-five (n = 35) deep and shallow tube well samples across an area of approximately 306 sq. km. Key physicochemical parameters indicate that the water ranges from slightly acidic to near neutral (average pH 6.91), with low turbidity (avg. 1.31 NTU), and a redox environment varying from reducing to oxidizing (ORP –77.4 to 153 mV).

Elemental analysis conducted using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) reveals that most parameters, including chloride (20.46 mg/L) and zinc (0.11 mg/L) fall within permissible limits. However, iron (0.38 mg/L), cadmium (0.002 mg/L), lead (0.004 mg/L) and fluoride (7.86 mg/L) concentrations exceed World Health Organization (WHO) thresholds in several locations, signaling localized contamination risks. Fluoride distribution mapping shows a spatial imbalance, with two-thirds of the study area exhibiting excess fluoride and one-fourth showing deficiency; both of which may cause dental and skeletal health issues.

The Water Quality Index (WQI) classifies 40% of the samples as "excellent" and 60% as "good" for drinking purposes. Despite this, challenges such as over-extraction of aquifers, unplanned urban growth, and increasing industrialization continue to threaten groundwater sustainability and quality. The study emphasizes the urgent need for an integrated groundwater management framework that incorporates pollution control measures, equitable water distribution, periodic quality monitoring, and public health awareness campaigns. These actions are essential to preserving groundwater resources and ensuring long-term water security for the growing urban population.

Keywords: ***Groundwater, Geochemistry, Water Quality Index, Management challenges.***

Introduction

Dhaka City, one of the fastest-growing megacities in the world, depends heavily on groundwater to meet its domestic, industrial, and agricultural water demand. Over-extraction, coupled with limited surface water availability, has placed the aquifer system under severe stress (Shamsudduha et al., 2011). Contamination from natural geogenic processes and anthropogenic sources further complicates the quality scenario (Jarup, 2003). Groundwater safety is therefore a critical concern for sustainable urban development and public health management in Bangladesh.

This study presents a geochemical characterization of groundwater in Dhaka City and highlights its management challenges. By integrating water quality assessment with spatial distribution analysis, the work provides insights into health implications and long-term sustainability.

Methodology

Groundwater samples (n = 35) were collected from shallow (depth < 100 m) and deep (> 100 m) tube wells within an area of approximately 306 sq. km. Physicochemical parameters such as Electrical conductivity (EC), Hydrogen ion concentration (pH), Oxidation Reduction Potential (ORP), Dissolved Oxygen (DO), Total Dissolved Solid (TDS), Salinity, Resistivity and Temperature (T) were measured in situ. Major and trace elements were analyzed using ICP-OES at the Geological Survey of Bangladesh.

WQI was computed using the Weighted Arithmetic Index method (Brown et al., 1972) with WHO (2017) standards. ArcGIS 10.8 supported spatial analysis of fluoride and heavy metal distribution.

Results and Discussion

Physicochemical properties: pH ranged 6.2–7.5 (avg. 6.91), turbidity was low (1.31 NTU), and ORP varied widely, reflecting heterogeneous aquifer conditions.

Elemental analysis: Most concentrations were within WHO limits, except localized exceedances: cadmium >0.003 mg/L in six sites, lead >0.01 mg/L in four sites, iron >1 mg/L in two sites, and fluoride >1.5 mg/L in 67% of the study area (Figure 1). Fluoride distribution maps indicated dual risks: excess fluoride linked to skeletal fluorosis, and deficiency linked to dental caries (Ayoob and Gupta, 2006).

Water Quality Index: Table 1 summarizes the WQI classification. No samples fell into "poor" or worse categories but localized heavy metal hotspots highlight potential health risks (Figure 2).

Management Challenges

Key issues include:

Over-extraction: Aquifer depletion due to unregulated pumping for municipal supply and industries.

Pollution pressure: Industrial effluents and urban leachates contribute to cadmium and lead contamination.

Spatial heterogeneity: Variability in fluoride distribution complicates mitigation.

Institutional gaps: Lack of coordinated management between city authorities, water utilities, and environmental agencies.

Table 1, Water Quality Index classification.

WQI Value	Water Quality	Water Samples (%)
<50	Excellent	40.00
50–100	Good water	60.00
100–200	Poor water	0
200–300	Very poor water	0
>300	Water unsuitable for drinking	0

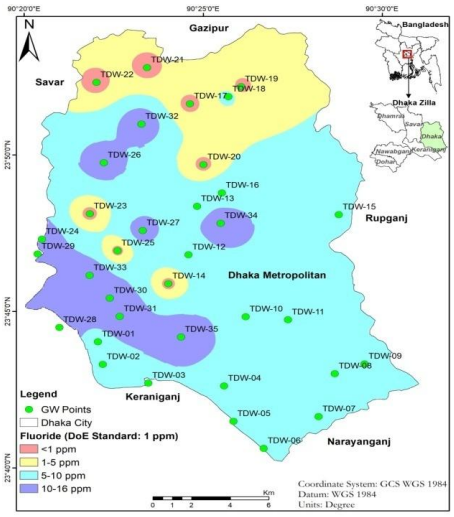

Figure 1, Floride distribution map in the study area.

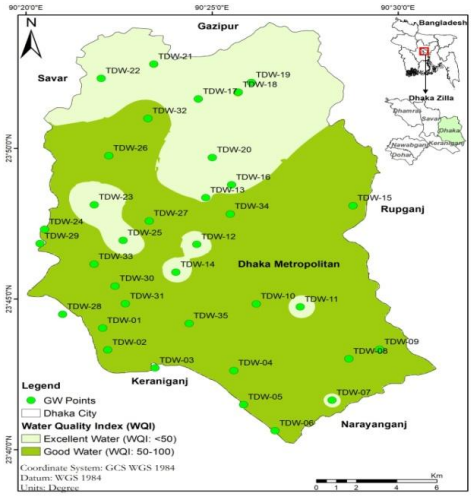

Figure 2, WQI map for groundwater samples in Dhaka Metropolitan City.

A sustainable groundwater management strategy should integrate periodic monitoring, stricter regulation of industrial discharges, and community-level awareness.

Conclusion

This study highlights that while most of the Dhaka's groundwater is classified as "good to excellent," contamination risks from heavy metals and fluoride imbalances present localized but significant threats to human health. Without integrated management measures, the twin challenges of over-extraction and contamination will undermine long-term groundwater sustainability. A framework involving pollution control, regulated pumping, equitable distribution, and health awareness is critical for securing urban water security in Dhaka.

Acknowledgement

The authors gratefully acknowledge the Director General of the Geological Survey of Bangladesh for approval to conduct this study and Dhaka WASA officials for their support during fieldwork.

References

Ayoob, S., and Gupta, A. K. (2006). Fluoride in drinking water: A review on the status and stress effects. Critical Reviews in Environmental Science and Technology, 36 (6), 433–487. https://doi.org/10.1080/10643380600678112

Brown, R. M., McClelland, N. I., Deininger, R. A., and Tozer, R. G. (1972). A water quality index—do we dare? Water and Sewage Works, 117 (10), 339–343.

Jarup, L. (2003). Hazards of heavy metal contamination. British Medical Bulletin, 68 (1), 167–182. https://doi.org/10.1093/bmb/ldg032

Shamsudduha, M., Chandler, R. E., Taylor, R. G., and Ahmed, K. M. (2011). Recent trends in groundwater levels in a highly seasonal hydrological system: The Ganges–Brahmaputra–Meghna Delta. Hydrology and Earth System Sciences, 15, 1533–1545. https://doi.org/10.5194/hessd-6-4125-2009

World Health Organization. (2017). Guidelines for drinking-water quality (4th ed.). WHO, Geneva.